

इंटरनेट

मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

“जानने का अधिकार, जीने का अधिकार”

Mazdoor Kisan Shakti Sangathan

“The Right to Information, The Right to Live”

“पुराने को छोड़ नये के तरफ”

Jawaharlal Nehru

“Step Out From the Old to the New”

IS 4247-3 (1998): Code of practice for structural design of surface hydel power stations, Part 3: Substructure [WRD 15: Hydroelectric Power House Structures]



“ज्ञान से एक नये भारत का निर्माण”

Satyanarayan Gangaram Pitroda

“Invent a New India Using Knowledge”



“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”

Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

BLANK PAGE



भारतीय मानक

सतह पनबिजली केन्द्रों की संरचना डिजाइन की रीति संहिता

भाग 3 उपसंरचना

(दूसरा पुनरीक्षण)

Indian Standard

**CODE OF PRACTICE FOR STRUCTURAL
DESIGN OF SURFACE HYDEL
POWER STATIONS**

PART 3 SUB-STRUCTURE

(Second Revision)

ICS 27.140

© BIS 1998

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Hydroelectric Power House Structures Sectional Committee had been approved by the River Valley Division Council.

This standard (Part 3) was first published in 1970. The present revision has been made to reflect the experience gained in the field since then and to align its provisions with those of Part 1 and Part 2 of the standard.

Stability analysis and design of substructure of a surface hydro power station are important items and require thorough attention. Hydrel power station is essentially a gravity structure acted upon by a number of forces in different combinations and stability and safety of substructure has to be ensured both under normal and extraordinary combination of forces.

This standard has been published in parts. This part is intended to help the designer in making reasonable assessment of the forces likely to be involved in stability analysis and design of substructure of a surface hydrel power station. Data for design have been covered in Part 1 and superstructure in Part 2.

Since the site conditions and the forces may vary from one power station to another to a considerable extent, it may not be possible to strictly conform to the provisions laid down in the standard. Under such circumstances the engineer-in-charge is required to use his discretion and he may make such modifications as he considers necessary due to some special features of the power station or the actual site conditions.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

CODE OF PRACTICE FOR STRUCTURAL DESIGN OF SURFACE HYDEL POWER STATIONS

PART 3 SUB-STRUCTURE

(*Second Revision*)

1 SCOPE

This standard (Part 3) lays down general recommendations for the stability analysis of a surface hydel power station and also provides design criteria for its substructure.

2 REFERENCES

The Indian Standards listed below are necessary adjuncts to this standard:

<i>IS No.</i>	<i>Title</i>	<i>IS No.</i>	<i>Title</i>
432 (Part 1) : 1982	Mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement: Part 1 Mild steel and medium tensile steel bars (<i>third revision</i>)	1893 : 1984	Criteria for earthquake resistant design of structures (<i>fourth revision</i>)
456 : 1978	Code of practice for plain and reinforced concrete (<i>third revision</i>)	1904 : 1986	Code of practice for design and construction of foundations in soils: General requirements (<i>third revision</i>)
457 : 1957	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures	2062 : 1992	Weldable structural steel (<i>third revision</i>)
800 : 1984	Code of practice for general construction in steel (<i>second revision</i>)	3370	Code of practice for concrete structures for the storage of liquids: General requirements
807 : 1976	Code of practice for design, manufacture, erection and testing (structural portion) of cranes and hoists (<i>first revision</i>)	(Part 1) : 1965	Reinforced concrete structures
875	Code of practice for design loads (other than earthquake) for buildings and structures:	(Part 2) : 1965	Code of practice for structural design of surface hydroelectric power stations:
(Part 2) : 1987	Imposed loads (<i>second revision</i>)	4247	(Part 1) : 1993 Data for design — Code of practice (<i>third revision</i>)
(Part 3) : 1987	Wind loads (<i>second revision</i>)	(Part 2) : 1992	Superstructure (<i>second revision</i>)
1566 : 1982	Hard-drawn steel wire fabric for concrete reinforcement (<i>second revision</i>)	4410 (Part 10) : 1988	Glossary of terms relating to river valley projects: Part 10 Hydroelectric power station including water conductor system (<i>first revision</i>)
1786 : 1985	High strength deformed steel bars and wires for concrete reinforcement (<i>third revision</i>)		

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 4410 (Part 10) shall apply.

4 DESIGN DATA

For the design of a surface hydro power station, the data to be collected should be in accordance with IS 4247 (Part 1).

5 MATERIALS

5.1 Concrete

Plain and reinforced concrete should conform to IS 456 and mass concrete shall conform to IS 457.

5.2 Structural Steel

The structural steel shall conform to IS 2062.

5.3 Reinforcement Steel

The reinforcement steel shall conform to IS 432 (Part 1), IS 1786 and IS 1566.

6 STABILITY ANALYSIS

6.1 Hydel power station is essentially a gravity structure which is generally quite rigid and this standard covers only such cases. Stability analysis has to be carried out for each monolith of the power station to ensure that the structure is stable to resist the worst probable combination of loads and forces. In case of monoliths in which installation of power units is deferred, stability should be investigated for the interim as well as the final conditions of loading. The following factors should be determined in the analysis of stability of the structure, as a whole:

- Overturning and bearing pressure,
- Settlement,
- Shear friction factor, and
- Floatation factor.

6.1.1 Individual loads and forces should be separately evaluated for ascertaining the possible combinations to give worst effect as given in 6.2.

6.2 Combinations of Loads and Forces

The following combinations of loads and forces acting at the power station should be considered for carrying out the stability analysis (for loading conditions, see 6.3).

Sl No.	Loads and Forces	Combination
i)	Dead load of the structure including permanently embedded parts such as scroll case and draft tube liner, etc	Full load
ii)	Removable machine and equipment loads, such as turbine, generator, transformers and main inlet valve	Zero/Full load
iii)	Live load of floors (see Note 1)	Zero/full load/as per IS 875 : (Part 3)
iv)	Crane loads including crane surges and horizontal thrusts, etc (see also IS 807, IS 875 (Part 2) and IS 4247 (Part 1))	Zero/crane moving loaded to half its capacity/stationary unloaded crane/crane stationary loaded to full capacity
v)	Wind loads in accordance with IS 875 (Part 3)	Full load in either direction/zero when considering

Sl No.	Loads and Forces	Combination
		seismic load or maximum design flood
vi)	Penstock thrust including water hammer	Zero/full thrust
vii)	Weight of water likely to be transmitted to the power station building, such as water in the spiral casing, draft tube, downstream/upstream ledge, if any.	Cases with draft tube and penstock/spiral case empty/full
viii)	Backfill pressure	Full (see Note 2)
ix)	Pressure due to tail water	Minimum/normal/maximum tail water level
x)	Water pressure from upstream due to saturation/head water pressure	Existing normal ground water table/saturation level
xi)	Uplift pressure	Zero/full
xii)	Pull of conductors fixed on building	Zero/full load
xiii)	Seismic forces in accordance with IS 1893	Zero/full (see Note 3)

NOTES

1 The live loads specified in IS 4247 (Part 1) may be suitably reduced in the case of multistoreyed power station building, since all the floors of such a building are not likely to be fully loaded simultaneously.

2 Cases when the power station is commissioned before the backfill is done, should also be checked.

3 With seismic loads consider only minimum/normal water levels.

6.2.1 The uplift should be assumed to act on full base and to have a straight line variation between points of known pressures. In case any pressure release arrangement, such as drainage galleries, is provided, suitable reduction in the uplift pressure at the location of such arrangement may be made and the uplift pressure diagram modified accordingly.

6.3 Loading Conditions

Stability analysis of the structure should be carried out for the worst probable combination of loads but should include only those loads which have reasonable probability of simultaneous occurrence. The following loading conditions should be considered:

- Normal loading conditions, and
- Extraordinary loading conditions.

6.3.1 Normal Loading Conditions

Existing normal ground water table/saturation level should be considered with normal/minimum tailwater level. Cases for removable equipment, being/not being, in position with draft tube, spiral casing and penstock being empty/full should also be considered. Crane load should be considered by assuming the

crane to be moving loaded to half its capacity or stationary loaded to full capacity. Seismic, wind and high flood conditions should not be considered under normal loading conditions.

6.3.2 Extraordinary Loading Conditions

When the seismic forces are considered, wind load and maximum flood levels should not be considered and the crane should be assumed unloaded and stationary.

6.3.3 If the installation of generating equipment is deferred and second stage concrete is not provided, analysis, shall also be carried out for such conditions with appropriate loads.

6.4 Overturning and Bearing Pressures

The resultant of all the forces at foundation level under worst probable condition of loading should fall well within the middle-third of base. The eccentricity due to the worst combination of loading on the foundation should be worked out to ascertain the maximum bearing pressure which should not exceed the allowable value (see 6.4.4).

6.4.1 Where the structure rests on two or more different strata, the foundation pressure diagram, should be modified taking into account the ratio of moduli of deformation of the different strata of the foundation.

6.4.2 In case the calculations of the bearing pressures indicate tension in any part of the foundation and no anchors are provided to take this tension, the base pressure diagram should be modified to exclude the part of the foundations where such tension is indicated.

6.4.3 Sometimes, where the foundation rock is suitable, it may be possible to separate the draft tube base slab from the draft tube piers. In such cases the base slab area should not be considered effective in transference of power house loads to the subgrade. In such case draft tube slab should have to be anchored with the foundation rock against uplift pressure and suitable waterstop should be provided between draft tube slab and piers.

6.4.4 Allowable Bearing Pressures

The allowable bearing pressures should be worked out from the actual bearing tests carried out at site at the foundation level preferably under saturated condition. However, for preliminary studies, the allowable bearing pressure may be taken as specified in IS 1904.

6.4.4.1 The increase in permissible bearing pressures for seismic condition should be in accordance with IS 1893 and for wind it shall be in accordance with IS 875 (Part 3).

6.5 Settlement

The magnitude and distribution of the probable settlement should be investigated and special provision made in the design of the structure to prevent such differential settlement as it may cause tilt in the turbine generator shaft beyond permissible limits. The permissible limit of the tilt should be decided in consultation with the manufacturers of turbine-generator.

6.6 Shear Friction Factor

The shear friction factor (Q_1) between the structure and its foundation shall be determined by the following equation:

$$Q_1 = \frac{CA + f\Sigma V}{\Sigma H}$$

where

C = cohesion or unit shearing strength in kgf/cm^2 applied only to area in compression,

A = area of the base under compression in cm^2 ,

f = coefficient of friction,

ΣV = algebraic sum of the normal forces and the uplift in kg, and

ΣH = algebraic sum of the forces parallel to the plane of sliding in kg.

6.6.1 For determining the shear friction factor within the foundation strata, f in the formula in 6.6 should be substituted by $\tan \theta$, where θ is the angle of internal friction of the foundation material.

6.6.2 The value of C and θ vary for different foundation materials and concrete. These values should be determined by experiment. However, for preliminary design the values recommended in IS 4247 (Part 1) may be used.

6.6.3 The value of shear friction factor should not be less than the following:

	Completed	Construction Stage
For normal loading condition	3.5	2.5
For extraordinary loading condition	2.0	1.1

6.6.4 To achieve the minimum factors of safety as in 6.6.3, it may sometimes be necessary to increase the base area or to add concrete keys monolithic with the foundation slab.

6.7 Floatation Factor

Floatation of the structure may occur on account of the uplift forces caused by water. The factor of safety against floatation shall be worked out by $F = \Sigma V/U$

where ΣV is the sum of all the vertical loads except that due to uplift which is denoted by U . The factor of safety against floatation should not be less than the following:

- Construction stage (first stage concrete up to 1.1 maximum TWL only)/Extraordinary loading condition
- Power house completed and equipment installed 1.25

6.7.1 Where the requirements of safety against floatation as in 6.7 and 7.1.1 are not achieved economically by increasing the weight of concrete and by provision of apron on the upstream along with drainage galleries to reduce uplift, then, anchor bars grouted into the monolithic foundation rock (provided the rock is suitable), may be provided to achieve the desired factor of safety.

6.7.2 Sometimes, where the foundation rock is suitable, it is possible to reduce the uplift pressure by separating out the draft tube base slab from the draft tube piers and by providing adequate drainage holes drilled in the rock through the bottom slab. When the draft tube is de-watered, the excessive uplift pressure is relieved through these drainage holes, thus reducing the possibility of damage to the bottom slab. In such cases, the bottom slab is generally anchored to the rock.

7 SUB-STRUCTURE FOUNDATION TREATMENT

7.1 Depending upon the foundation conditions, the desirability of improving the foundation strata by consolidation grouting and/or dental treatment may be examined.

7.1.1 Suitable sub-surface drainage may be provided in order to reduce uplift pressures and increase stability of the structure against floatation. Where artesian conditions exist below the foundation level, sand wells suitably arranged around the power station may be provided to relieve such pressures.

7.1.2 While designing the sub-surface drainage arrangements, care should be taken that there is no possibility of piping out of the material through the drainage system.

7.1.3 Sometimes, foundation material is such that it disintegrates on short exposure. In such cases, it is necessary to preserve the natural characteristics of the unexposed foundation material either by delaying the excavation of the last 1 to 2 metres of the material until just prior to placing concrete, or by excavating to final grade and immediately applying a concrete protective coat.

8 VIBRATION ANALYSIS

Vibrations caused by various impressed forces and their adverse effects on power station structure should be checked in all sizable and important power houses.

9 STRUCTURAL DESIGN

9.1 Design Loads

9.1.1 Dead Loads

These shall consist of self-load of the structure and the equipment loads. Concentrated loads due to equipment, column loads, etc, should be assumed to be dispersed suitably.

9.1.2 Live Loads

Live loads shall be taken in accordance with IS 4247 (Part 1).

9.1.3 Seismic Load

These shall be taken in accordance with IS 1893.

9.1.4 Water Pressures

Appropriate value of the water pressure shall be considered, where applicable.

9.1.5 Shrinkage Effects

Stresses due to shrinkage strain in concrete shall be taken into account.

9.1.6 Backfill Pressures

These shall be considered where applicable.

9.1.7 Foundation Pressures

These shall be worked out in accordance with 6.4.

9.2 Stresses

9.2.1 Permissible Stresses

The permissible stresses in concrete and reinforcement shall be taken in accordance with IS 456. The permissible stress in structural steel shall be taken in accordance with IS 800. Reduction in permissible stresses, if any, for components of power station in contact with water shall be in accordance with IS 3370 (Part 1) and IS 3370 (Part 2).

9.2.2 Increase in Permissible Stresses

The design of the substructure should be checked for combination of loads as given below with the corresponding increase in permissible stresses:

Loading	Increase in Permissible Stresses, Percent
Normal loading conditions	0
Extraordinary loading conditions	33.33

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act, 1986* to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publication), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Handbook' and 'Standards Monthly Additions'.

This Indian Standard has been developed from Doc: No. RVD 15 (144).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 323 01 31, 323 33 75, 323 94 02

Telegrams: Manaksanstha
(Common to all offices)

Regional Offices:

Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg
NEW DELHI 110002

Telephone
323 76 17, 323 38 41

Eastern : 1/14 C.I.T. Scheme VII M, V.I.P. Road, Maniktola
CALCUTTA 700054

{ 337 84 99, 337 85 61
337 86 26, 337 91 20

Northern : SCO 335-336, Sector 34-A, CHANDIGARH 160022

{ 60 38 43
60 20 25

Southern : C.I.T. Campus, IV Cross Road, CHENNAI 600113

{ 235 02 16, 235 04 42
235 15 19, 235 23 15

Western : Manakalaya, E9 MIDC, Marol, Andheri (East)
MUMBAI 400093

{ 832 92 95, 832 78 58
832 78 91, 832 78 92

Branches : AHMADABAD. BANGALORE. BHOPAL. BHUBANESHWAR.
COIMBATORE. FARIDABAD. GHAZIABAD. GUWAHATI.
HYDERABAD. JAIPUR. KANPUR. LUCKNOW. NAGPUR.
PATNA. PUNE. THIRUVANANTHAPURAM.